



UNIVERSITI PUTRA MALAYSIA

**CHEMICAL CONSTITUENTS AND BIOLOGICAL ACTIVITIES OF
SELECTED CINNAMOMUM SPECIES (LAURACEAE) AND
MELICOPSE CF. HOOKERII T.G. HARTLEY (RUTACEAE)**

NOR AZAH BINTI MOHAMAD ALI.

FSAS 2004 33

**CHEMICAL CONSTITUENTS AND BIOLOGICAL ACTIVITIES OF
SELECTED *CINNAMOMUM* SPECIES (LAURACEAE) AND *MELICOPE*
CF. *HOOKERI* T.G. HARTLEY (RUTACEAE)**

By

NOR AZAH MOHAMAD ALI

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,
in Fulfilment of the Requirements for the Degree of Doctor of Philosophy**

June 2004



Dedicated to my parents, my husband, Mokhlis Maizan and my children



Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

**CHEMICAL CONSTITUENTS AND BIOLOGICAL ACTIVITIES OF
SELECTED *CINNAMOMUM* SPECIES (LAURACEAE) AND *MELICOPE*
CF. *HOOKERI* T.G. HARTLEY (RUTACEAE)**

By

NOR AZAH BINTI MOHAMAD ALI

June 2004

Chairman: Professor Mawardi Rahmani, Ph.D.

Faculty: Science and Environmental Studies

The essential oils of nine *Cinnamomum* species (*C. sintoc*, *C. pubescens*, *C. impressiscostatum*, *C. subavenium*, *C. microphyllum*, *C. scortechinii*, *C. rhyncophyllum*, *C. aureofulvum* and *C. verum*) were investigated by means of gas chromatography (GC) and combination of gas chromatography/mass spectrometer (GC/MS). The chemical components of the essential oils (leaf, stem bark and twig oils) were identified by co-chromatography with authentic samples on three columns of different polarity, comparison with Kovats retention indices, capillary GC/MS and proton NMR on selected isolated components. The essential oils were made up of one, two or all three of the following class of compounds; monoterpenes and sesquiterpenoids, phenylpropanoids and benzyl esters. Some of the chemical components observed in the oils are (*E*)-methyl cinnamate, safrole, benzyl benzoate, linalool, terpinen-4-ol and camphor which are commercially important chemicals in the flavour and pharmaceutical industries. The distribution and occurrences of

specific compounds in different parts of the plants among the different species may be used as a chemotaxonomic marker for species identification.

Cinnamomum species (*C. impressicostatum*, *C. pubescens*, *C. microphyllum*) and *Melicope* cf. *hookeri* were selected for a study of their chemical constituents and biological properties. All of these species have not been reported previously on their chemical constituents. Phytochemical analysis of the bark and stem parts of *C. impressicostatum* yielded safrole (15), (*E*)-methyl cinnamate (17), (*E*)-piperonylprop-2-enal (116), cinnamic acid (117) and β -sitosterol (118). Similar analysis on the bark of *C. pubescens* also afforded safrole (15), (*E*)-methyl cinnamate (17), (*E*)-piperonylprop-2-enal (116) and β -sitosterol (118) as well as (*E*)-piperonylprop-2-enol (119). Antimicrobial test using the disc diffusion method showed that the chloroform and the hexane extract of the two species contained almost solely (*E*)-methyl cinnamate, which were active against fungus. The presence of (*E*)-piperonyl-2-enal (116) and (*E*)-piperonylprop-2-enol (119) were reported for the first time from the genus *Cinnamomum*.

Phytochemical investigation on the stem and bark of *Cinnamomum microphyllum* resulted in the isolation of a coumarin; scoparone (120), benzyl benzoate (4), β -sitosterol (118) and mixtures of pinoresinol-type lignans; pinoresinol (121), syringaresinol (37) and medioresinol (122). The lignan mixture was found to possess significant antioxidant activity against three antioxidant assays;

autooxidation of linoleic acid, xanthine/xanthine oxidase superoxide scavenging assay and DPPH radical scavenging activity.

Phytochemical investigation on the leaves and bark of *Melicope* cf. *hookeri* T.G. Hartley resulted in the isolation of three flavonoids, two coumarins and sterols. The three flavonoids; ayanin (**57**), ombuin (**123**) and kumatakenin (**124**) together with β -sitosterol (**118**) were isolated from the leaves. The bark extract afforded ayanin (**57**), β -sitosterol (**118**), umbelliferone (**102**) and scopoletin (**125**). Crude extracts of *M. cf. hookeri* were screened for antimicrobial activity, antioxidant activity and TPA-induced ear oedema assay. The extracts failed to show significant antimicrobial or antioxidant activity. However, the leaf ethyl acetate extract showed strong anti-inflammatory activity with the chloroform extract (95%) and methanol extract (92%) showing the highest inhibitions as compared to the petroleum ether extract (70%). The presence of flavonoid compounds in the species probably contribute to the anti-inflammatory activity of the plant extracts.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

**KOMPONEN KIMIA DAN AKTIVITI BIOLOGI TERHADAP SPESIES
TERPILIH *CINNAMOMUM* (LAURACEAE) DAN *MELICOPE* CF.
HOOKERI T.G. HARTLEY (RUTACEAE)**

Oleh

NOR AZAH BINTI MOHAMAD ALI

June 2004

Pengerusi: Profesor Mawardi Rahmani, Ph.D.

Fakulti : Sains dan Pengajian Alam Sekitar

Kandungan minyak pati sembilan spesies *Cinnamomum* (*C. sintoc*, *C. pubescens*, *C. impressiscostatum*, *C. subavenium*, *C. microphyllum*, *C. scortechinii*, *C. rhyncophyllum*, *C. aureofulvum* dan *C. verum*) telah dikaji dengan menggunakan kromatografi gas (GC) dan gabungan kromatografi gas/spectrometer jisim (GC/MS). Komponen-komponen bahagian minyak pati tersebut (daun, kulit kayu dan ranting) telah dicamkan dengan kaedah ko-kromatografi dengan sampel tulen menggunakan tiga turus kapilari yang mempunyai polariti yang berbeza, perbandingan dengan Indeks Penahanan Kovats, perbandingan spektrum jisim dengan spektrum jisim rujukan dan pengecaman proton NMR terhadap komponen yang berjaya dipisahkan. Kandungan minyak pati yang dikaji didapati mengandungi satu, dua atau ketiga-tiga sebatian kimia berikut; monoterpenoid dan seskuiterpenoid, fenilpropanoid dan benzilik ester. Antara komponen kimia yang sering dijumpai dalam minyak pati *Cinnamomum* ialah metil sinamat, safrol, benzil benzoat, linalool, terpinen-4-ol dan kamfor iaitu bahan kimia penting yang digunakan secara komersil dalam industri

perisa dan farmaseutikal. Taburan dan kewujudan komponen kimia tertentu dalam bahagian pokok yang berbeza di kalangan spesies *Cinnamomum* yang berbeza boleh digunakan sebagai penunjuk kemotaksonomi dalam pengecaman spesies.

Spesies *Cinnamomum* (*C. impressicostatum*, *C. pubescens*, *C. microphyllum*) dan *Melicope* cf. *hookeri* telah dipilih untuk kajian kimia dan aktiviti biologi. Kandungan komponen kimia kesemua spesies ini belum pernah dilaporkan. Kajian fitokimia yang dijalankan terhadap kulit dan batang *Cinnamomum impressicostatum* menghasilkan safrol (15), (*E*)-metil sinamat (17), (*E*)-piperonilprop-2-enal (116), asid sinamik (117) dan β -sitosterol (118). Kajian pemencilan terhadap kulit *C. pubescens* pula telah menghasilkan sebatian kimia yang sama; safrol (15), (*E*)-metil sinamat (17), (*E*)-piperonilprop-2-enal (116), β -sitosterol (118) dan (*E*)-piperonilprop-2-enol (119). Kajian antimikrob menggunakan kaedah peresapan cakera terhadap kulat (*C. albicans*, *C. lipolytica*) menunjukkan bahawa ekstrak heksana dan kloroform yang mengandungi komponen (*E*)-metil sinamat adalah sangat aktif. Kehadiran (*E*)-piperonilprop-2-enal (116) dan (*E*)-piperonilprop-2-enol (119) pertama kali dilaporkan dari genus *Cinnamomum*.

Kajian terperinci terhadap kulit kayu *Cinnamomum microphyllum* menghasilkan pengecaman sebatian koumarin, skoparon (120), benzil benzoat (4), β -sitosterol (118) dan sebatian lignan iaitu pinoresinol (121), siringaresinol (37) dan medioresinol (122). Gabungan sebatian lignan ini telah didapati memberikan aktiviti antioksidan yang signifikan terhadap tiga esei antioksidan; autooksidasi asid

linoleik, ujian penyingkiran superoksida zantina/zantina oksida dan ujian penyingkiran radikal bebas DPPH.

Kajian fitokimia terhadap daun dan kulit *Melicope cf. hookeri* T.G. Hartley telah menghasilkan pemencilan tiga sebatian flavonoid, dua koumarin dan sterol. Tiga sebatian flavonoid; ayanin (57), ombuin (123) dan kumatakenin (124) bersama-sama β -sitosterol (118) telah dipencilkan daripada bahagian daun. Bahagian kulit batang pula telah menghasilkan sebatian ayanin (57), β -sitosterol (118) umbeliferon (102) dan skopoletin (125). Ekstrak mentah *M. cf. hookeri* telah diuji terhadap esei antimikrob, antioksidan dan anti radang. Kesemua ekstrak yang dikaji gagal menunjukkan keputusan aktiviti antimikrob dan antioksidan yang signifikan. Walau bagaimanapun, ekstrak kloroform daun *M. cf. hookeri* menunjukkan aktiviti anti radang yang tertinggi (95%) berbanding dengan ekstrak metanol (92%) dan petroleum eter (70%). Kehadiran sebatian flavonoid di dalam spesies ini berkemungkinan mempengaruhi aktiviti anti-radang ekstrak tumbuhan tersebut.

ACKNOWLEDGEMENTS

All praises be to Allah, Lord of the universe. Only by His grace and mercy can this thesis be completed.

I wish to express my sincere thanks to all of my supervisors; Prof. Dr. Mawardi Rahmani, Prof. Dr. Abd. Manaf Ali and Assoc. Prof. Dr. Khozirah Shaari for their invaluable guidance and continuous encouragement and support throughout the course of the program.

I also wish to express my sincere gratitude to Dato' Dr. Abdul Razak Mohd. Ali, Director General Of Forest Research Institute Malaysia (FRIM), Dr. Baskaran Krisnapillay, Senior Director of Biotechnology Division and Dr. Rasadah Mat Ali, Director of Medicinal Plants Programme, respectively for their constant interest and encouragements.

Thanks are also due to all of the staff of Medicinal Plants Division for their continuing support and skilful technical assistance especially Mohd. Faridz Zolpatah, Abu Said Ahmad, Alisbana Ali, Siti Asha Abu Bakar, Mastura Mohtar, Vimala Subramaniam, Rohana Shahdan and Abd. Majid Jalil. My special thanks to Norseha Ayob and Mat Asri Ngah Samah for their help in the collection and identification of plant materials. I am also grateful for all the help given by the technical staff of Institute BioScience and Chemistry Department of Universiti Putra Malaysia.

I am also grateful for the encouragement and moral support given by my family especially my dearest husband, Mokhlis Maizan and my parents Mohd. Ali and Rahimah and all of my children; Mohamin, Mustaqim, Mirya Athirah, Muammar, Maria Amalia and Myra Adlina for being patient and understanding.



I certify that an Examination Committee met on 9th June 2004 to conduct the final examination of Nor Azah Mohamad Ali on her Doctor of Philosophy thesis entitled "Chemical Constituents and Biological Activities of Selected *Cinnamomum* Species (Lauraceae) and *Melicope* CF. *hookeri* T.G. Hartley (Rutaceae)" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

MOHD. ASPOLLAH SUKARI, Ph.D.

Associate Professor
Faculty of Science and Environmental Studies
Universiti Putra Malaysia
(Chairman)

MAWARDI RAHMANI, Ph.D.

Professor
Faculty of Science and Environmental Studies
Universiti Putra Malaysia
(Member)

ABDUL MANAF ALI, Ph.D.

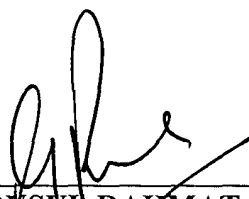
Professor
Institute of Bioscience
Universiti Putra Malaysia
(Member)

KHOZIRAH SHAARI, Ph.D.

Associate Professor
Institute of Bioscience
Universiti Putra Malaysia
(Member)

HASNAH MOHD. SIRAT, Ph.D.

Chemistry Department
Faculty of Science
Universiti Teknologi Malaysia
(Member)



GULAM RUSUL RAHMAT ALI, Ph.D.

Professor/Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 26 AUG 2004

This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee are as follows:

MAWARDI RAHMANI, Ph.D.

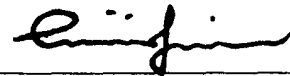
Professor
Department of Chemistry
Faculty of Science and Environmental studies
Universiti Putra Malaysia
(Chairman)

ABDUL MANAF ALI, Ph.D.

Professor
Institute of Bioscience
Universiti Putra Malaysia
(Member)

KHOZIRAH SHAARI, Ph.D.

Associate Professor
Institute of Bioscience
Universiti Putra Malaysia
(Member)



AINI IDERIS, Ph.D.
Professor/Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: **10 SEP 2004**

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.



NOR AZAH BINTI MOHAMAD ALI

Date: 19/7/24

TABLE OF CONTENTS

DEDICATION	Page ii
ABSTRACT	iii
ABSTRAK	vi
ACKNOWLEDGEMENTS	ix
APPROVAL	x
DECLARATION	xii
LIST OF TABLES	xviii
LIST OF FIGURES	xx
LIST OF ABBREVIATIONS	xxiv

CHAPTER

I	INTRODUCTION TO THE GENUS CINNAMOMUM	
	The Genus <i>Cinnamomum</i> (Lauraceae)	1
	Uses of the Genus <i>Cinnamomum</i>	2
	Selection of <i>Cinnamomum</i> Species for This Work	4
	The Genus <i>Melicope</i> (Rutaceae)	9
	<i>Melicope</i> cf. <i>Hookeri</i> T.G. Hartley	11
	Research and Economic Potential of Medicinal and Aromatic Plants in Malaysia	12
	Objectives of the Present Work	14
II	LITERATURE REVIEW	
	Chemistry and Biological Activities of the Genus <i>Cinnamomum</i>	15
	Previous Work on <i>Melicope</i> Species	35
III	EXPERIMENTAL	
	General Procedures	49
	Plant Material	50
	Essential Oil Preparation	51
	Chemical Analysis	51
	Kovats Retention Indices	52
	Procedure for Calculating Retention Indices	53
	Solvent Extraction	54
	Extraction and Isolation of <i>Cinnamomum</i> species	54
	Extraction of <i>Cinnamomum</i> species	54



Isolation of Compounds from <i>C. impressicostatum</i> Bark <i>n</i> -Hexane Extract	55
Spectral Properties of Isolated Compounds	
Safrole (15)	56
(<i>E</i>)-Methyl Cinnamate (17)	57
(<i>E</i>)-Piperonylprop-2-enal (116)	57
Isolation of Compounds from <i>C. impressicostatum</i> Bark Chloroform Extract	58
Spectral Properties of Isolated Compounds	
Safrole (15)	59
(<i>E</i>)-Methyl Cinnamate (17)	59
(<i>E</i>)-Piperonylprop-2-enal (116)	59
Cinnamic Acid (117)	59
Bio-assay Guided Fractionation of <i>C. pubescens</i> Bark Extract	60
Extraction and Bioassay	60
Compounds Isolated from <i>C. pubescens n</i> -Hexane Extract	61
Spectral Properties of Isolated Compounds	
Safrole (15)	62
(<i>E</i>)-Methyl Cinnamate (17)	62
(<i>E</i>)-Piperonylprop-2-enal (116)	62
β -Sitosterol (118)	62
Isolation of (<i>E</i>)-Piperonylprop-2-enol (119)	63
Spectral Properties of Isolated Compounds	
Safrole (15)	64
(<i>E</i>)-Methyl Cinnamate (17)	64
(<i>E</i>)-Piperonylprop-2-enal (116)	64
(<i>E</i>)-Piperonylprop-2-enol (119)	65
Isolation of Compounds from <i>C. microphyllum</i> Stem Chloroform Extract	65
Scoparone (120)	66
Isolation of Pinoresinol-type Lignans	66
Isolation of Compounds from <i>C. microphyllum</i> Bark <i>n</i> -Hexane Extract	67
Spectral Properties of Isolated Compounds	
Benzyl Benzoate (4)	68
β -Sitosterol (118)	68
Compounds Isolated from <i>C. microphyllum</i> Bark Chloroform Extract	68
Spectral Properties of Isolated Compounds	
Pinoresinol (121)	69
Syringaresinol (37)	70
Medioresinol (122)	71
Extraction and Isolation of <i>Melicope</i> cf. <i>hookeri</i>	72
Compounds Isolated from <i>Melicope</i> cf. <i>hookeri</i>	72

Leaf Petroleum Ether Extract	
Spectral Properties of Isolated Compounds	73
β -sitosterol (118)	73
Ayanin (57)	73
Compounds Isolated from <i>Melicope</i> cf. <i>hookeri</i>	74
Leaf Ethyl Acetate Extract	
Spectral Properties of Isolated Compounds	
Ayanin (57)	75
Ombuin (123)	75
Kumatakenin (124)	76
Compounds Isolated from the Leaf Methanol Extract	77
Ayanin (57)	77
Kumatakenin (124)	77
Compounds Isolated from <i>Melicope</i> cf. <i>hookeri</i>	78
Bark Extract	
Isolation of β -Sitosterol (118)	78
Isolation of Umbelliferone (102)	78
Spectral Properties of Isolated Compounds	
Umbelliferone (102)	79
Ayanin (57)	80
Scopoletin (125)	80
Bioassays	81
Antimicrobial Assay	81
Disc Diffusion Assay	82
Bio-assay Guided Fractionation Using Disc Diffusion Method	82
Thin Layer Chromatographic Bioautography	83
Minimum Inhibitory Concentration (MIC)	83
Antioxidant Assays	84
Autooxidation of Linoleic Acid in a Water-Alcohol System	84
Xanthine/Xanthine Oxidase (X/XOD)	85
Superoxide Scavenging Assay	
2,2-Diphenyl-1-Picrylhydrazyl (DPPH)	86
Free Radical Scavenging Assay	
Reduction of DPPH	86
Cytotoxicity Assay	87
Cell Cultures	87
MTT Cytotoxicity Assay	87
Anti-Tumour Promoting Assay	88
<i>In-vitro</i> Inhibition of Eipstein-Barr Virus (EBV) Assay	88
Anti-Inflammatory Assay	90
TPA-Induced Mouse Ear Oedema Assay	90

IV RESULTS AND DISCUSSION

Quantitative and Qualitative Analysis of <i>Cinnamomum</i> Essential Oils	92
Identification of Chemical Constituents of Essential Oils	93
Chemical Composition of the Essential oils of <i>Cinnamomum</i> Species	94
The Essential Oils of <i>C. sintoc</i>	94
The Essential Oils of <i>C. pubescens</i>	100
The Essential Oils of <i>C. scortechinii</i>	108
The Essential Oils of <i>C. microphyllum</i>	113
The Essential Oils of <i>C. subavenium</i>	113
The Essential Oils of <i>C. impressicostatum</i>	119
The Essential Oils of <i>C. rhyncophyllum</i>	123
The Essential Oils of <i>C. aureofulvum</i>	128
The Essential Oils of <i>C. zeylanicum</i>	133
Chemical Variation in the Essential Oils of <i>Cinnamomum</i> Species	141
Extraction and Isolation of Chemical Constituents from <i>Cinnamomum</i> Species	144
Characterisation of Compounds Isolated from <i>Cinnamomum impressicostatum</i>	144
Safrole (15)	144
(E)-Methyl Cinnamate (17)	151
(E) -Piperonylprop-2-enal (116)	157
Cinnamic Acid (117)	164
Characterisation of Compounds Isolated from <i>C. pubescens</i>	169
Safrole (15)	169
(E)-Methyl Cinnamate (17)	169
(E) -Piperonylprop-2-enal (116)	169
β -Sitosterol (118)	169
(E)-Piperonylprop-2-enol (119)	177
Characterisation of Compounds Isolated from <i>C. microphyllum</i>	185
Scoparone (120)	185
Benzyl Benzoate (4)	193
β -Sitosterol (118)	200
Pinoresinol (121)	200
Syringaresinol (37)	216
Medioresinol (122)	231
Extraction and Isolation of Chemical Constituents from <i>Melicope</i> Species	249
Characterisation of Compounds Isolated from <i>Melicope</i> cf. <i>hookeri</i>	249

Ayanin (57)	249
Ombuin (123)	261
Kumatakenin (124)	272
β -Sitosterol (118)	285
Umbeliferone (102)	285
Scopoletin (125)	292
Bioassays	
Antimicrobial Activity	297
Antimicrobial Activity of <i>Cinnamomum</i> Essential Oils	298
Antimicrobial Activity of <i>Cinnamomum</i> Plant Extracts	302
Bio-assay Guided Fractionation	306
Antimicrobial Activity of (<i>E</i>)-Methyl Cinnamate (17)	307
Bio-assay Guided Fractionation of <i>C. pubescen</i> Bark Extracts	307
Antioxidant	311
Antioxidant Assays	312
Antioxidant Assay on Fractionated <i>Cinnamomum</i> Extracts	314
Antioxidant Activity of Purified Compounds	318
Anti-tumour Promoting Activity	319
Cytotoxicity Activity of <i>Cinnamomum</i> Extracts and Essential oils	322
Biological Activities of Crude Extracts of <i>Melicope</i> cf. <i>hookeri</i> T.G. Hartley	325
Antimicrobial Activity	325
Antioxidant Activity	326
Anti-inflammatory Activity	327
V CONCLUSION	329
REFERENCES	333
APPENDICES	347
BIODATA OF THE AUTHOR	349

LIST OF TABLES

Table		Page
1	Major essential oil constituents or chemotypes of the genus <i>Cinnamomum</i>	23
2	The plant extracts of <i>Cinnamomum</i> species	55
3	The leaves and stem bark extracts of <i>Melicope</i> cf. <i>hookeri</i>	72
4	Yield of <i>Cinnamomum</i> essential oils	92
5	Chemical constituents of the essential oils of <i>C. sintoc</i>	99
6	Chemical constituents of the essential oils of <i>C. pubescens</i>	107
7	Chemical constituents of the essential oils of <i>C. scortechinii</i>	112
8	Chemical constituents of the essential oils of <i>C. microphyllum</i> and <i>C. subavenium</i>	118
9	Chemical constituents of the essential oils of <i>C. impressicostatum</i>	123
10	Chemical constituents of the essential oils of <i>C. rhyncophyllum</i>	128
11	Chemical constituents of the essential oils of <i>C. aureofulvum</i>	132
12	Chemical constituents of the essential oils of <i>C. zeylanicum</i>	140
13	Percentage distribution of the major components in the essential oils of <i>Cinnamomum</i> species	143
14	¹ H-NMR and ¹³ C-NMR data for pinoresinol (121)	203
15	¹ H-NMR and ¹³ C-NMR data for syringaresinol (37)	219
16	¹ H-NMR and ¹³ C-NMR data for medioresinol (122)	234
17	¹ H-NMR and ¹³ C-NMR data for ayanin (57)	251
18	¹ H-NMR and ¹³ C-NMR data for ombuin (123)	263
19	¹ H-NMR and ¹³ C-NMR data for kumatakenin (124)	274
20	Minimum inhibitory concentrations (µg/µl) of <i>Cinnamomum</i> essential oils and essential oil standards	301
21	Antimicrobial activity of <i>Cinnamomum</i> crude methanol extracts	304
22	Selected plant extracts and their zones of inhibition against microorganisms	305
23	Antimicrobial activity of <i>C. impressicostatum</i> bark extracts	306
24	Minimum inhibitory concentrations (MIC) µg/µl	307
25	Plant extracts of <i>Cinnamomum pubescens</i> and their zones of inhibition against microorganisms	309
26	Anti-methicillin resistant <i>Staphylococcus aureus</i> (MRSA) activity	310
27	Antioxidant activity of <i>Cinnamomum</i> plant extracts	313
28	Antioxidant activity of selected <i>Cinnamomum</i> extracts	315
29	Antioxidant activity of essential oils	317
30	Antioxidant activities of the essential oils of <i>C. zeylanicum</i>	318
31	Antioxidant activity of purified compounds	319
32	Anti-tumour promoting activities of <i>Cinnamomum</i> extracts and essential oils (35 µg/ µl)	321
33	Cytotoxic activity of <i>Cinnamomum</i> plant extracts and essential	324



oils

34	Antimicrobial activity of <i>Melicope</i> cf. <i>hookeri</i> extracts	326
35	Antioxidant activities of the extracts of <i>Melicope</i> cf. <i>hookeri</i>	327
36	Effect of <i>Melicope</i> cf. <i>hookeri</i> extracts on mouse ear oedema induced by TPA	328



LIST OF FIGURES

Figure		Page
1	Chemical components from <i>Cinnamomum</i> essential oils	26
2	Gas chromatogram obtained using capillary SE-30 column for the leaf oil of <i>C. sintoc</i>	96
3	Gas chromatogram obtained using capillary DB-5 column for the bark oil of <i>C. sintoc</i>	97
4	Gas chromatogram obtained using capillary SE-30 column for the twig oil of <i>C. sintoc</i>	98
5	Gas chromatogram obtained using capillary DB-5 column for the leaf oil of <i>C. pubescens</i> (Sample A)	102
6	Gas chromatogram obtained using capillary DB-5 column for the leaf oil of <i>C. pubescens</i> (Sample B)	103
7	Gas chromatogram obtained using capillary DB-5 column for the bark oil of <i>C. pubescens</i> (Sample C)	104
8	Gas chromatogram obtained using capillary DB-5 column for the bark oil of <i>C. pubescens</i> (Sample D)	105
9	Gas chromatogram obtained using capillary DB-5 column for the twig oil of <i>C. pubescens</i>	106
10	Gas chromatogram obtained using capillary SE-30 column for the leaf oil of <i>C. scortechinii</i>	109
11	Gas chromatogram obtained using capillary SE-30 column for the stem bark oil of <i>C. scortechinii</i>	110
12	Gas chromatogram obtained using capillary SE-30 column for the twig oil of <i>C. scortechinii</i>	111
13	Gas chromatogram obtained using capillary SE-30 column for the leaf oil of <i>C. microphyllum</i>	114
14	Gas chromatogram obtained using capillary SE-30 column for the bark oil of <i>C. microphyllum</i>	115
15	Gas chromatogram obtained using capillary SE-30 column for the leaf oil of <i>C. subavenium</i>	116
16	Gas chromatogram obtained using capillary SE-30 column for the twig oil of <i>C. subavenium</i>	117
17	Gas chromatogram obtained using capillary DB-5 column for the leaf oil of <i>C. impressicostatum</i>	121
18	Gas chromatogram obtained using capillary DB-5 column for the stem bark oil of <i>C. impressicostatum</i>	122
19	Gas chromatogram obtained using capillary SE-30 column for the leaf oil of <i>C. rhyncophyllum</i>	125
20	Gas chromatogram obtained using capillary SE-30 column for the stem bark oil of <i>C. rhyncophyllum</i>	126
21	Gas chromatogram obtained using capillary SE-30 column for the twig oil of <i>C. rhyncophyllum</i>	127
22	Gas chromatogram obtained using capillary DB-5 column for the leaf oil of <i>C. aureofulvum</i>	130

23	Gas chromatogram obtained using capillary DB-5 column for the bark oil of <i>C. aureofulvum</i>	131
24	Gas chromatogram obtained using capillary DB-5 column for the leaf oil of <i>C. zeylanicum</i>	135
25	Gas chromatogram obtained using capillary DB-5 column for the bark oil of <i>C. zeylanicum</i>	136
26	Gas chromatogram obtained using capillary DB-5 column for the wood oil of <i>C. zeylanicum</i>	137
27	Gas chromatogram obtained using capillary DB-5 column for bark sample A	138
28	Gas chromatogram obtained using capillary DB-5 column for bark sample B	139
29	Infrared spectrum of safrole (15)	146
30	Mass spectrum of safrole (15)	147
31	¹ H-NMR spectrum of safrole (15)	148
32	¹³ C-NMR spectrum of safrole (15)	149
33	DEPT spectrum of safrole (15)	150
34	IR spectrum of (<i>E</i>)-methyl cinnamate (17)	153
35	Mass spectrum of (<i>E</i>)-methyl cinnamate (17)	154
36	¹ H-NMR spectrum of (<i>E</i>)-methyl cinnamate (17)	155
37	¹³ C-NMR spectrum of (<i>E</i>)-methyl cinnamate (17)	156
38	IR spectrum of (<i>E</i>)-piperonylprop-2-enal (116)	159
39	Mass spectrum of (<i>E</i>)-piperonylprop-2-enal (116)	160
40	¹ H-NMR spectrum of (<i>E</i>)-piperonylprop-2-enal (116)	161
41	COSY spectrum of (<i>E</i>)-piperonylprop-2-enal (116)	162
42	¹³ C-NMR spectrum of (<i>E</i>)-piperonylprop-2-enal (116)	163
43	IR spectrum of cinnamic acid (117)	165
44	Mass spectrum of cinnamic acid (117)	166
45	¹ H-NMR spectrum of cinnamic acid (117)	167
45a	Expanded ¹ H-NMR spectrum of cinnamic acid (117)	168
46	IR spectrum of β -sitosterol (118)	171
47	Mass spectrum of β -sitosterol (118)	172
48	¹ H-NMR spectrum of β -sitosterol (118)	173
49	¹³ C-NMR spectrum of β -sitosterol (118)	174
49a	Expanded ¹³ C-NMR spectrum of β -sitosterol (118)	175
49b	Expanded ¹³ C-NMR spectrum of β -sitosterol (118)	176
50	Mass spectrum of (<i>E</i>)-piperonyl-2-enol (119)	179
51	IR spectrum of (<i>E</i>)-piperonyl-2-enol (119)	180
52	¹ H-NMR spectrum of (<i>E</i>)-piperonyl-2-enol (119)	181
53	COSY spectrum of (<i>E</i>)-piperonyl-2-enol (119)	182
54	¹³ C-NMR spectrum of (<i>E</i>)-piperonyl-2-enol (119)	183
55	DEPT spectrum of (<i>E</i>)-piperonyl-2-enol (119)	184
56	IR spectrum of scoparone (120)	187
57	Mass spectrum of scoparone (120)	188
58	¹ H-NMR spectrum of scoparone (120)	189
59	¹³ C-NMR spectrum of scoparone (120)	190

60	DEPT spectrum of scoparone (120)	191
61	XHCORR spectrum of scoparone (120)	192
62	Mass spectrum of benzyl benzoate (4)	195
63	IR spectrum of benzyl benzoate (4)	196
64	¹ H-NMR spectrum of benzyl benzoate (4)	197
65	¹³ C-NMR spectrum of benzyl benzoate (4)	198
65a	Expanded ¹³ C-NMR spectrum of benzyl benzoate (4)	199
66	IR spectrum of pinoresinol (121)	204
67	Mass spectrum of pinoresinol (121)	205
68	¹ H-NMR spectrum of pinoresinol (121)	206
69	COSY spectrum of pinoresinol (121)	207
69a	Expanded COSY spectrum of pinoresinol (121)	208
70	¹³ C-NMR spectrum of pinoresinol (121)	209
71	DEPT spectrum of pinoresinol (121)	210
72	HSQC spectrum of pinoresinol (121)	211
73	HMBC spectrum of pinoresinol (121)	212
73a	Expanded HMBC spectrum of pinoresinol (121)	213
73b	Expanded HMBC spectrum of pinoresinol (121)	214
73c	Expanded HMBC spectrum of pinoresinol (121)	215
74	Significant HMBC correlations for pinoresinol (121)	216
75	IR spectrum of syringaresinol (37)	220
76	Mass spectrum of syringaresinol (37)	221
77	¹ H-NMR spectrum of syringaresinol (37)	222
77a	Expanded ¹ H-NMR spectrum of syringaresinol (37)	223
77b	Expanded ¹ H-NMR spectrum of syringaresinol (37)	224
78	COSY spectrum of syringaresinol (37)	225
78a	Expanded COSY spectrum of syringaresinol (37)	226
79	¹³ C-NMR spectrum of syringaresinol (37)	227
80	DEPT spectrum of syringaresinol (37)	228
81	HSQC spectrum of syringaresinol (37)	229
82	HMBC spectrum of syringaresinol (37)	230
83	IR spectrum of medioresinol (122)	235
84	Mass spectrum of medioresinol (122)	236
85	¹ H-NMR spectrum of medioresinol (122)	237
85a	Expanded ¹ H-NMR spectrum of medioresinol (122)	238
85b	Expanded ¹ H-NMR spectrum of medioresinol (122)	239
86	¹³ C-NMR spectrum of medioresinol (122)	240
87	DEPT spectrum of medioresinol (122)	241
88	COSY spectrum of medioresinol (122)	242
88a	Expanded COSY spectrum of medioresinol (122)	243
88b	Expanded COSY spectrum of medioresinol (122)	244
89	HSQC spectrum of medioresinol (122)	245
90	HMBC spectrum of medioresinol (122)	246
90a	Expanded HMBC spectrum of medioresinol (122)	247
90b	Expanded HMBC spectrum of medioresinol (122)	248
91	IR spectrum of ayanin (57)	252



92	Mass spectrum of ayanin (57)	253
93	¹ H-NMR spectrum of ayanin (57)	254
93a	Expanded ¹ H-NMR spectrum of ayanin (57)	255
94	¹³ C-NMR spectrum of ayanin (57)	256
95	HSQC spectrum of ayanin (57)	257
95a	Expanded HSQC spectrum of ayanin (57)	258
95b	Expanded HSQC spectrum of ayanin (57)	259
96	HMBC spectrum of ayanin (57)	260
97	IR spectrum of ombuin (123)	264
98	Mass spectrum of ombuin (123)	265
99	¹ H-NMR spectrum of ombuin (123)	266
99a	Expanded ¹ H-NMR spectrum of ombuin (123)	267
100	¹³ C-NMR spectrum of ombuin (123)	268
101	HSQC spectrum of ombuin (123)	269
102	HMBC spectrum of ombuin (123)	270
102a	Expanded HMBC spectrum of ombuin (123)	271
103	IR spectrum of kumatakenin (124)	275
104	¹ H-NMR spectrum of kumatakenin (124)	276
104a	Expanded ¹ H-NMR spectrum of kumatakenin (124)	277
105	¹³ C-NMR spectrum of kumatakenin (124)	278
106	HSQC spectrum of kumatakenin (124)	279
107	HMBC spectrum of kumatakenin (124)	280
107a	Expanded HMBC spectrum of kumatakenin (124)	281
107b	Expanded HMBC spectrum of kumatakenin (124)	282
107c	Expanded HMBC spectrum of kumatakenin (124)	283
108	Mass spectrum of kumatakenin (124)	284
109	IR spectrum of umbelliferone (102)	287
110	Mass spectrum of umbelliferone (102)	288
111	¹ H-NMR spectrum of umbelliferone (102)	289
112	COSY spectrum of umbelliferone (102)	290
113	¹³ C-NMR spectrum of umbelliferone (102)	291
114	Mass spectrum of scopoletin (125)	293
115	¹ H-NMR spectrum of scopoletin (125)	294
115a	Expanded ¹ H-NMR spectrum of scopoletin (125)	295
115b	Expanded ¹ H-NMR spectrum of scopoletin (125)	296

LIST OF ABBREVIATIONS

α	Alpha
β	Beta
δ	Delta Chemical shift in ppm
γ	Gamma
λ_{\max}	Maximum wavelength in nm
μg	Microgram
μl	Microliter
$\mu\text{g}/\mu\text{l}$	Microgram/microliter
br	Broad
brs	Broad singlet
BHT	Butylated hydroxy toluene
^{13}C	Carbon-13
$^{\circ}\text{C}$	Degree celcius
cm^{-1}	Percentimeter
CDCl_3	Deuterated chloroform
CHCl_3	Chloroform
COSY	Correlated spectroscopy
CD_3OD	Deutrated methanol
CD_3COCD_3	Deuterated acetone
DEPT	Distortionless enhancement by polarisation transfer
d	Doublet
dd	Doublet of doublet
ddd	Doublet of doublet of doublet
DMSO	dimethylsulfoxide
DPPH	1,2-Diphenyl-2-picrylhydrazyl
eV	Electron volt
EC	Effective concentration
ED	Effective dose
EDTA	Ethylenediamine tetracetic acid
EIMS	Electron impact mass spectrometry
ELISA	Enzyme –linked Imunosorbent assay
EtOH	Ethanol
FCS	Fetal calf serum
g	Gram
m	Multiplet
FCS	Fetal calf serum
GC	Gas chromatography
GC/MS	Gas chromatography/mass spectrometer
^1H	proton
Hex	Hexane
HMBC	Heteronuclear Multiple Bond Connectivity by 2D multiple quantum

